CHAPTER 5: Operation Part 1

We will examine the normal operation of the boiler and then address emergencies and maintenance.

We have seen that the operation of a steam boiler can be summarized as follows:
1- Maintaining a specific steam pressure (corresponding to a single saturated steam temperature). This pressure depends on the "demand" or steam consumption and the amount of "fire" or fuel burned at any given time.
Since consumption is determined neither by the boiler operator nor the boiler itself, but rather by the process or location where the steam is used, the pressure will be maintained based on the amount of "fire" or combustion.

This balance between the amount of energy delivered by the boiler in the steam and the amount of energy delivered by combustion can be maintained manually or automatically (by regulating the fuel and air: continuous modulation, or by turning the burner on and off: "On-Off", or by regulating the air only: wood).

The difference between these two energies (steam and combustion) are the boiler losses (losses in the heat of the flue gases, heat losses from the boiler itself to the boiler room, water and steam losses in the boiler, purges).

2- **Maintain a specific water leve**l (covering the heat transfer surfaces, but not filling the steam chamber, which could lead to water being carried along with the steam: foaming, priming, carryover, etc.).

This water level (with minimum, normal, and high levels) can be maintained manually or automatically by regulating the feedwater inlet.

This level depends on, or tends to vary with, the steam demand or consumption, due to the need to evaporate a greater or lesser amount of water, and the need to replenish the feedwater to replace the evaporated water.

The feedwater can be regulated by: turning the feedwater pump on

and off (On/Off control), or by regulating the inlet valve or the feedwater pressure (continuous modulation).

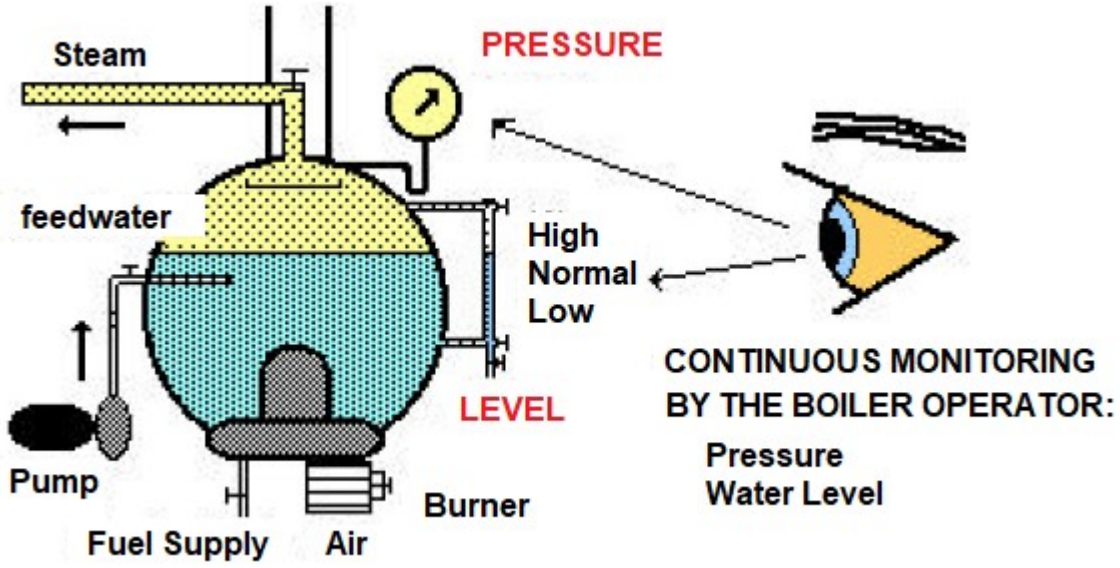
The level may vary due to temporary changes in the boiler's internal conditions (when a cold boiler is started, the level tends to rise as the water heats up; when there is a rapid increase or decrease in steam consumption, the water level appears to rise in the first case and falls in the second). Certain chemical conditions also cause the level to fluctuate.

In all these cases, caution should be exercised, as these are temporary conditions that do not always need to be corrected, since a momentarily low level can quickly become a high level.

The boiler operator must pay close attention to the pressure and water level, as these are the two variables necessary to operate the boiler, even if it is automatic, and these will be the first things to check when performing a maintenance check.

The balance between **the amount of steam and the amount of combustion** required is controlled by the **pressure**.

The balance between the **amount of steam and the amount of feedwater** required is controlled by the **water level**.



Constant monitoring of pressure and water level are the two fundamental aspects of boiler operation.

If we don't control the pressure (by adjusting the combustion quantity), the steam quality (temperature and humidity) will not be adequate for the process and safety. As pressure rises, we will depend on safety devices: **safety valves**.

If we don't control the water level, we can "burn out" the boiler due to a low level (overheating of the heat transfer surfaces or rupture with an "explosion"), or we can produce wet steam due to a high level (and even water carryover with "water hammer" that can cause equipment damage).

Combustion quality must be constantly monitored by observing the **appearance and color of the flame**, as well as the presence and color of the flue gases.

Alternatively, the air-fuel ratio can be monitored by reading the excess air required using instruments that measure oxygen or carbon dioxide in the flue gases.

This prevents the presence of carbon monoxide, excessive smoke, or an excess of air that could lead to greater losses in the flue gases.

Once the pressure and level are constant, we must focus on maintaining the conditions of the feedwater and the water inside the boiler.

To this end, the "ion exchanger" equipment (water softeners and demineralizers) will be monitored by taking samples periodically to control water quality (Total Hardness in softeners and Water Conductivity in demineralizers, etc.).

The temperature of the feed water must be kept at a preset value (as high as possible according to the feeding system) and care must be taken with the chemicals that must be introduced into the water (the quantity and the way of putting them in: continuous or discontinuous, etc.).

The **boiler water, monitored by analysis**, must be maintained within specific limits, not only by **adjusting the chemicals** used but also by regulating the amount of purges, both deep and

continuous.

For safety reasons, the level controls must be purged every 4 hours, ensuring the low-level alarm and shut-off are properly opened.

As we have seen, we must **remove the dissolved solids** (T.D.S.) and **sludge (salts and insoluble elements**, formed intentionally or by natural chemical reactions, depending on the quality of the makeup water, pipe oxides, etc.) from the boiler.

Bottom purge (which remove sludge and dissolved salts) should be performed at least once per shift and as often as necessary depending on the treatment and type of makeup water.

Open the valves fully during periods of minimal steam production, or better yet, with the boiler off. The sludge will tend to settle, lowering the level by one to three centimeters, depending on the boiler. Repeat the purge if necessary once the level has recovered.

With the boiler running: never purge water-walled collectors.

Check the proper functioning of the purge system by listening for the noise produced by the flow of water and flash steam.

Otherwise, the purge could be blocked by debris or precipitates. These could be elements that have fallen into the boiler during repair or inspection, or simply loose scale fragments stuck in the valves or piping.

In the case of the bottom purge, you can check for a drop in the water level, but not in the purge of the level controls.

A failure of the bottom or level purge can have serious consequences for the boiler's internal circulation (overheating) or can cause the level controls to malfunction (low water level failure).

The continuous purge should be opened as needed (it removes dissolved salts and affects the Total Dissolved Salts - TDS),

and generally fractions or liters per minute are removed, monitored with a measuring device (a graduated jug or "jar" at a specific time, which will be adjusted each shift).

There may be times when purge is necessary due to observations (like **excessive fluctuation in levels**: this could be due to insufficient purge or contamination of the boiler water, excessive bulk treatment, etc.).

In these cases, continuous purge should be performed until the level fluctuations subside (which can also be due to excessive or irregular steam consumption: in these cases, purge is not a priority, but it can help by lowering the chemical limits of the water, thus reducing the possibility of carryover), although it is advisable to shut off non-essential steam consumption.

Observe the appearance of the materials, especially in the combustion chamber, for signs of overheating or slag (clumps of unburned fuel) that could affect proper combustion. (Slag should be removed or broken up every shift.)

Purge the manual emergency level controls (level indicator valves) and test the safety valves at least once a week (by pulling the levers provided for this purpose).

In fuel oil burners, maintain the burner system at the specified conditions, temperatures, and pressures.

Clean the atomizing nozzles (or cups in rotary burners) periodically, taking care not to enlarge their orifices.

We have observed that if the fuel temperature drops, it becomes more difficult to pump and atomization is poor (producing soot even with excess air).

Check the auxiliary ignition system (propane in most cases; verify the gas supply and the pressure regulated to the ignition burner: pilot light).

Check for water leaks (pump and valve stem packing) and steam leaks. Cleaning the boiler and the room is essential.

BOILER START-UP

When starting a boiler, the first step is to check all the components involved in its operation:

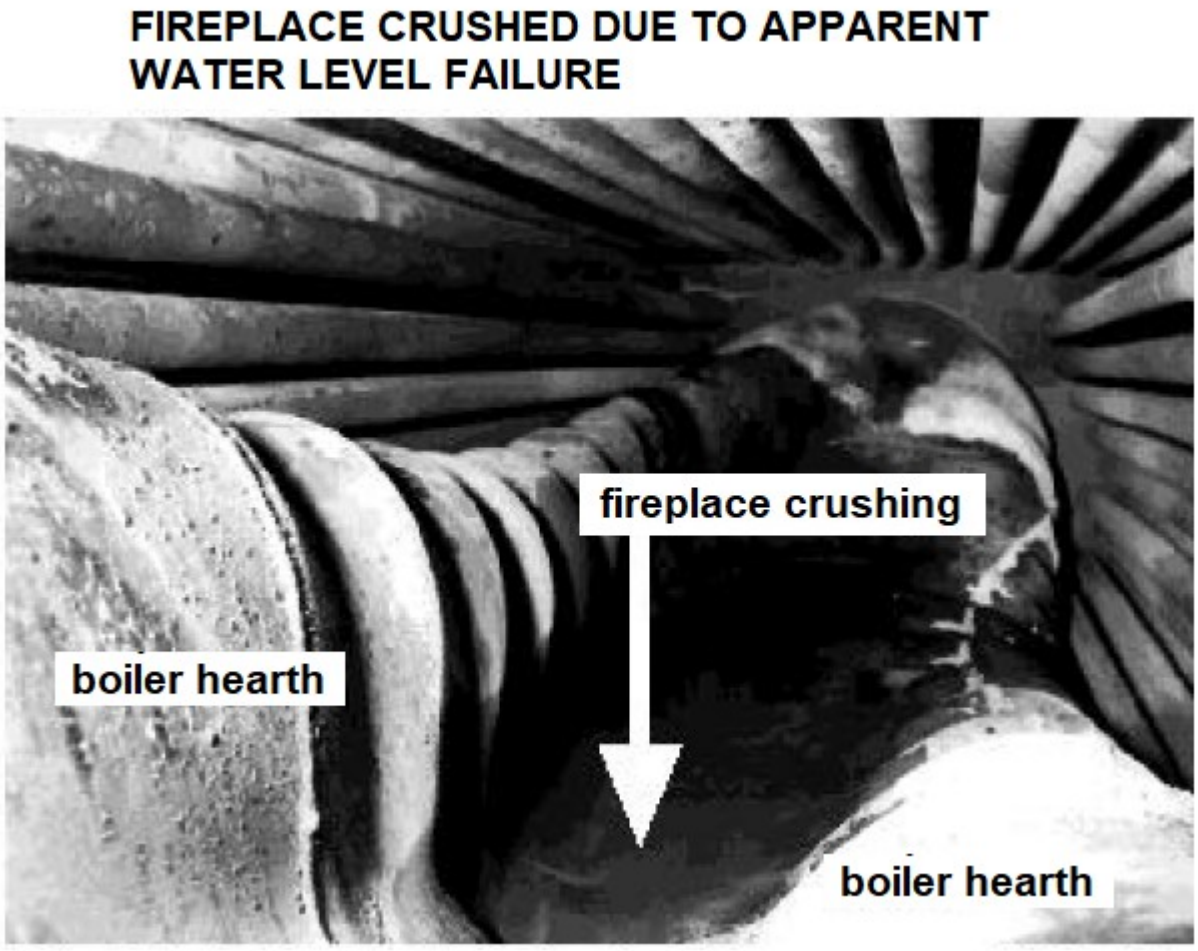
1- Verify that it is **filled with suitable water** (softened, chemically treated, etc.) to almost the normal level (1/4 of the visible level or the pump's automatic cut-off point, as the level will rise as the water temperature increases).

To fill the boiler, close all the purge valves and open the atmospheric valve (air vent).

It is assumed that the **main steam valve (throat valve) is closed**.

If the boiler is being "preserved" using a dry method, the drying agents (such as quicklime or silica gel) must first be removed, access panels installed, and a **leak test (hydraulic)** performed.

If it is flooded with treated water for a wet preservation method, it is generally sufficient to lower the water level by purging it down and opening the **atmospheric valve** to break the vacuum (allowing air to enter).



This failure of the firebox (crushing) occurs due to "lack of cooling," due to poor water circulation caused by various physical and chemical factors.

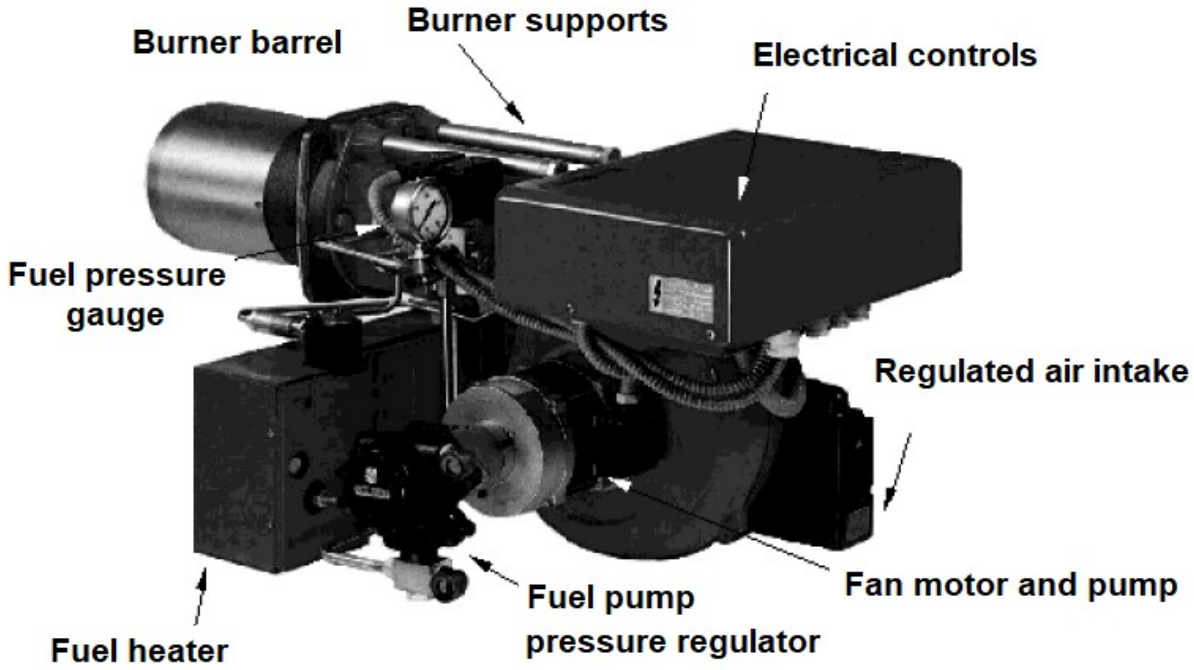
2- **Check the level controls switches** (open their purges and verify that they activate the **start/stop function of the feed pump** before opening its suction and discharge valves; listen and look for signs of low level).

In some cases, it is necessary to perform a **hydraulic "leak test"** (to check for water or steam leaks).

To do this, you can slowly build up the "working" pressure using the same **wáter feed pump**, venting the air through the **atmospheric valve** (the atmospheric valve serves both to vent air and gases and to prevent a "vacuum" from forming inside the boiler when cooling or emptying it).

After 10 minutes of pressure (with all valves closed), observe the exterior and interior of the boiler (firebox and smoke boxes) for water leaks, and ensure that the pressure on the gauge does not drop more than very slowly (this indicates a leak in the packing).

Then slowly release the pressure (purge) and adjust the boiler water level (opening and closing purge and atmospheric valve).



MECHANICALLY PRESSURIZED LIQUID FUEL BURNER

3- In Heavy Fuel Oil boilers (No. 6), check the fuel level in the service tank.

It is assumed that the fuel oil filters are clean and assembled.

Preheat with auxiliary heat (electric heating elements or auxiliary steam) to a pumpable temperature (40°C to 60°C) and do not attempt to pump without preheating (this can overload the pumps).

Then heat to the atomization temperature, which depends on the type of burner:

This can be: mechanical 120°C (248°F) to 145°C (293°F), steam and rotary cup 75°C (167°F) to 90°C (194°F), or low-pressure air 110°C (230°F) to 130°C (266°F).

These temperatures are approximate values; refer to the burner manufacturer. See heaters later in this chapter in the section dedicated to liquid fuels. Circulate the fuel oil slowly (taking care not to allow atomization) to ensure the system temperature and pressures normalize.

Next, before starting the burner, **check the induced draft** (or control openings in naturally draft chimneys), and **check the forced air** (primary and secondary air) by opening and closing their controls.

If the burner is automatic, it will perform the following steps automatically. However, if it is manual, proceed as follows:

a-No burner should be lit (nor its pilot light) before the combustion chamber has been "ventilated" (purged of combustible gases with clean air; otherwise, a combustion chamber explosion may occur).

The induced draft is fully opened, and the primary and secondary air valves are opened for a few seconds (90 seconds or more, until the combustion chamber and firebox are thoroughly purged of gases, **requiring at least four air changes**).

Then the primary and secondary air are closed to a "minimum" for starting and the induced draft until the depression (it is not always

done under depression or vacuum: 3 to 5 mm.W.C. (Water Column): millimeters of water column, many boilers work with the furnace "pressurized", with pressure in the furnace chamber, which can reach quite high values) in the furnace is the running pressure (generally we should notice suction in the sight glasses or pilot burner inlet).

If the pilot light is gas-powered and fixed, light it. If it's a manual, hemp-made pilot light, light it outside and insert it through the ignition port into the firebox (slightly forward and to the side of the burner). Observing the pilot flame through the sight glass (from the side), very gently open the fuel oil regulator valve until you obtain a small but stable flame.

Some boilers must be lit with low-viscosity fuels: "Gas Oil" or "Heating Fuel Oil." For these, you must first install a smaller nozzle or igniter than normal. An auxiliary atomizing device (air instead of steam) may also be necessary.

Once the flame has stabilized by adjusting the fuel, forced air, and combustion chamber pressure (until the flame is a bright red and does not tend to go out or blow out), the pilot light is extinguished or the burner (wax) is removed.

While the boiler is hot, do not attempt to light the burner using residual heat or flames remaining in the combustion chamber refractories (this can cause serious combustion explosions). Instead, perform the procedure described above.

The boiler must be heated slowly until steam is released from the atmospheric valve (visible steam, not air), as **rapid heating can cause tubes to loosen in the mandrels, refractory material to loosen, or cracks to appear in the boiler structure.**

This is due to the material's expansion, which must be uniform, because heat tends to rise (due to convection in the water and air, the top of the boiler will be hot and the bottom will be cold, with each meter of the boiler potentially expanding by more than 2 mm).

Care must be taken to ensure that this low flame does not go out when the boiler is cold (as it tends to be unstable).

In automatic burners, purging, pilot light ignition (if needed), flame monitoring (photocell: shuts off the fuel supply when it detects a lack of flame, preventing the combustion chamber from flooding with fuel), and fuel temperature control are all performed automatically each time the burner is ignited.

It will even prevent ignition if it detects a flame or a luminous heat source in the combustion chamber (or very cold fuel, or in some cases, insufficient air).

Some burners allow you to select a **low flame setting**; it is advisable to preheat the boiler using a low flame.

Some burners will not activate the **high flame** until a certain steam pressure is reached (this allows for slow heating and protects the cooling of the hottest plate at low pressures or during high steam consumption that could cause the pressure to drop too low).

In automatic burners, the mechanism that controls the purging, ignition, and flame control sequences is called a **"programmer" (generally electronic or electrica**l, although some may have contacts actuated mechanically by a motor that drives a camshaft).

In both manual and automatic burners, when starting them, a large amount of fuel should not be allowed to enter without ignition.

If ignition does not occur (ignition within a few seconds), the fuel supply should be shut off and the attempt repeated (after purging and, if necessary, adjusting for drafts or pressure in the combustion chamber, and temperatures, to prevent flame blowout).

When the steam pressure reaches 1 to 2 kg/cm² (15 to 30 psi), it is advisable to operate the bottom valves to remove the sludge deposited on the bottom and test the bottom purge mechanism (ensuring the valves operate correctly and do not leak).

Then, gradually increase combustion by adding more fuel (either by increasing the fuel pressure or using larger fuel pellets, as needed) and increasing the air and draft. Maintain a medium flame until the operating pressure is reached.

Test the burner cut-off from the levels (by purging them),

test for the lack of flame in the photoresistor cell (automatic burner all: remove the photocell and cover it from the light,

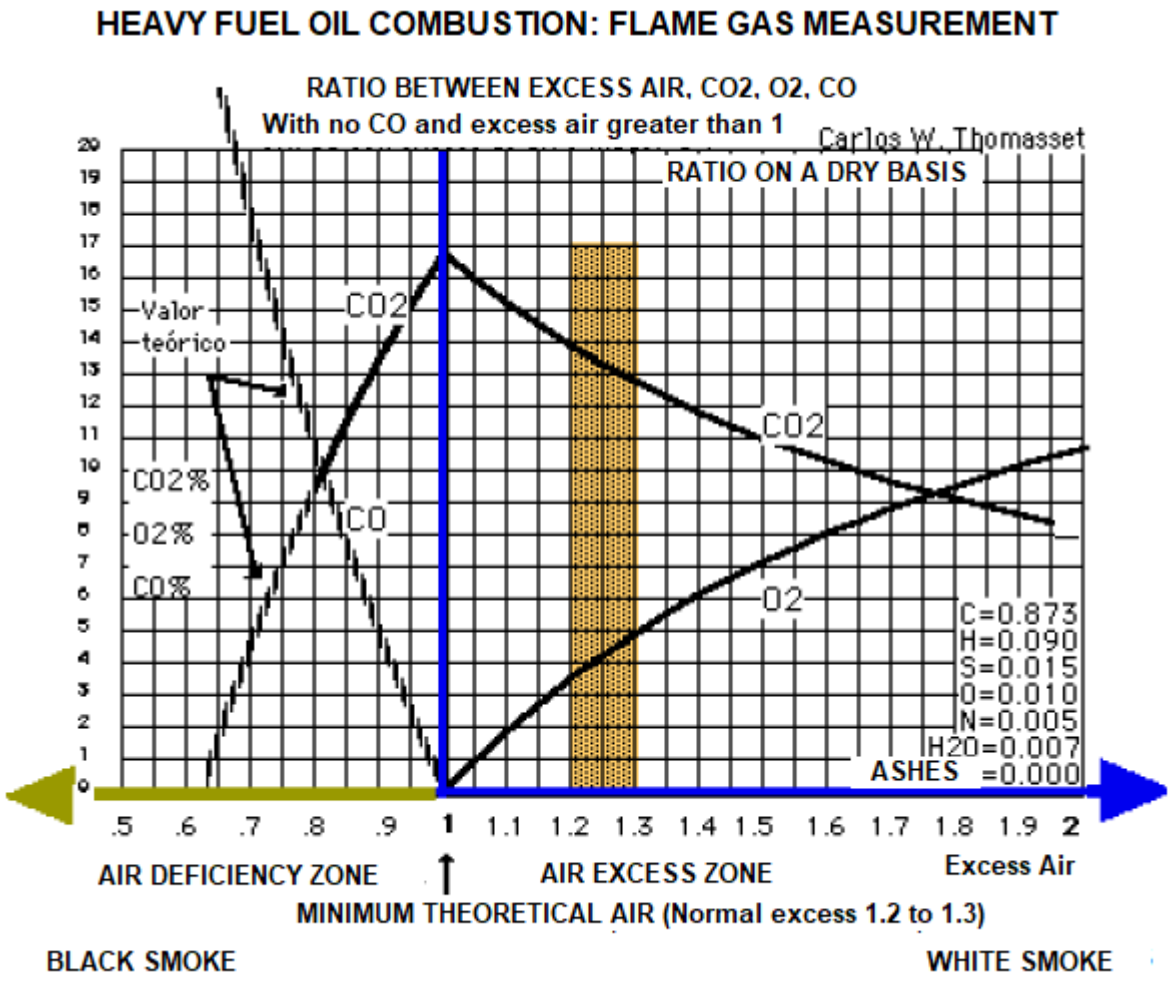
the burner should turn off).

Once the system is secure and the boiler is steaming at the **working pressure,** slowly open the **steam outlet valve** (steam supply valve) (very slowly, or open a bypass in the case of high pressures or large valves).

Then fully open the valve (avoiding "scoring": scoring of the seat due to rolling: steam throttling).

Once the steam consumption is established, the water and fuel feed will need to be increased to maintain the balance of the water level inside the boiler and its steam pressure (which will tend to vary with consumption).

When the pressure drops due to **increased steam consumption**, we must increase combustion by increasing the amount of air and fuel in a related manner, and if the steam pressure increases, we must lower the combustion rate by lowering the fuel and air in the same ratio (air/fuel ratio).


HEAVY FUEL OIL COMBUSTION: FLAME GAS MEASUREMENT
RATIO BETWEEN EXCESS AIR, CO2, O2, CO
With no CO and excess air greater than 1
Carlos W. Thomasset
RATIO ON A DRY BASIS
Valor teórico
CO2
CO2%
O2%
CO%
CO
CO2
O2
C=0.873
H=0.090
S=0.015
O=0.010
N=0.005
H20=0.007
ASHES =0.000
.5 .6 .7 .8 .9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2
AIR DEFICIENCY ZONE
AIR EXCESS ZONE
Excess Air
MINIMUM THEORETICAL AIR (Normal excess 1.2 to 1.3)
BLACK SMOKE
WHITE SMOKE

Fuel Oil Combustion Regulation:

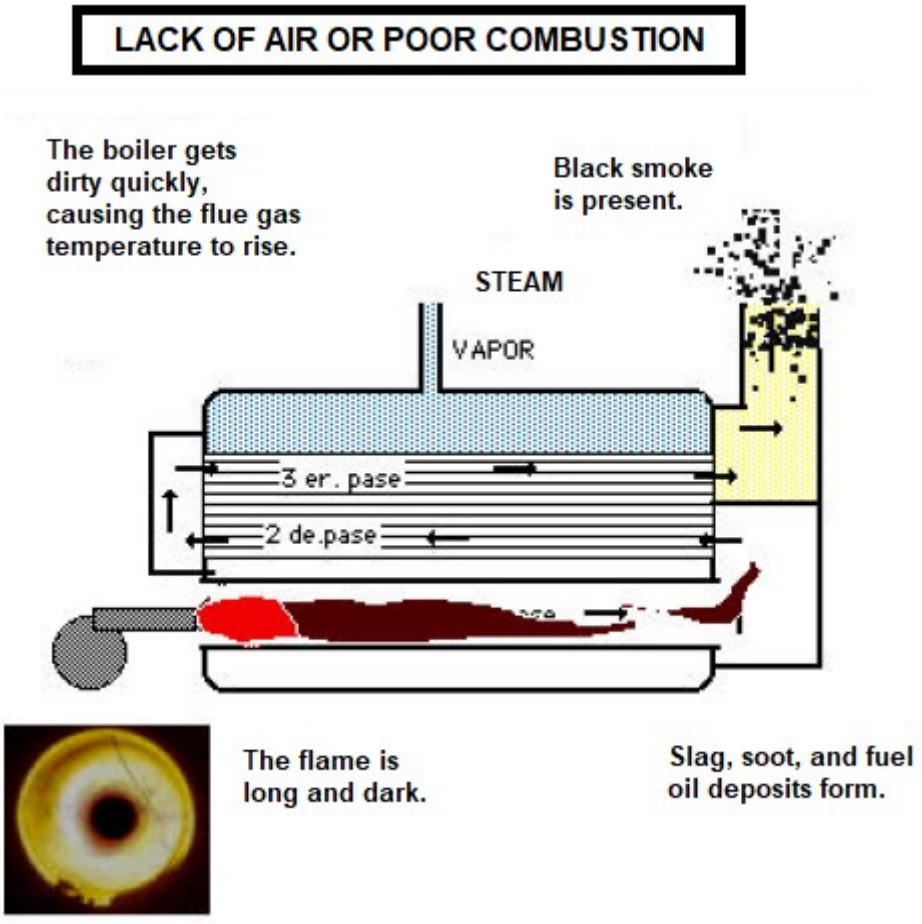
We have seen that for each kg of fuel, a certain minimum amount of air is required (more than 14 kg of air per kg of fuel oil), since we need an excess of air to achieve good combustion (free of smoke and soot).

This can be controlled using flue gas composition meters, but from a practical point of view, this is insufficient and such measuring equipment is not usually available. Therefore, we must judge combustion based on our visual observation.

We must observe the flame color and appearance: the color of the flue gases.

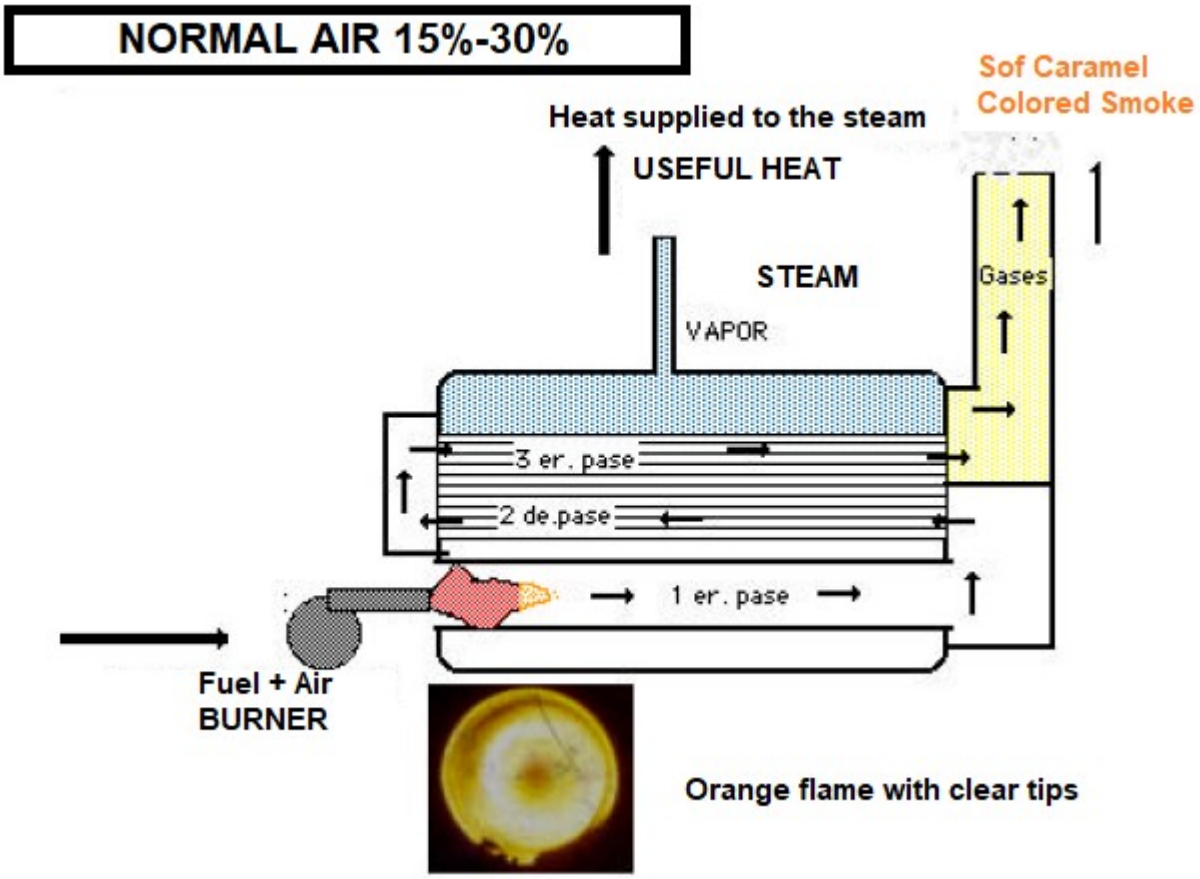
1-Lack of air:

the flame is dark red and long, there is black or dark brown smoke in the chimney (CO_2 is more than 14% and O_2 less than 3.5%, there may be CO and/or soot; CO may not form, but soot may. These values depend on the minimum excess air required for the type of burner).


LACK OF AIR OR POOR COMBUSTION
The boiler gets dirty quickly, causing the flue gas temperature to rise.
Black smoke is present.
STEAM
VAPOR
3 er. pase
2 de.pase
The flame is long and dark.
Slag, soot, and fuel oil deposits form.

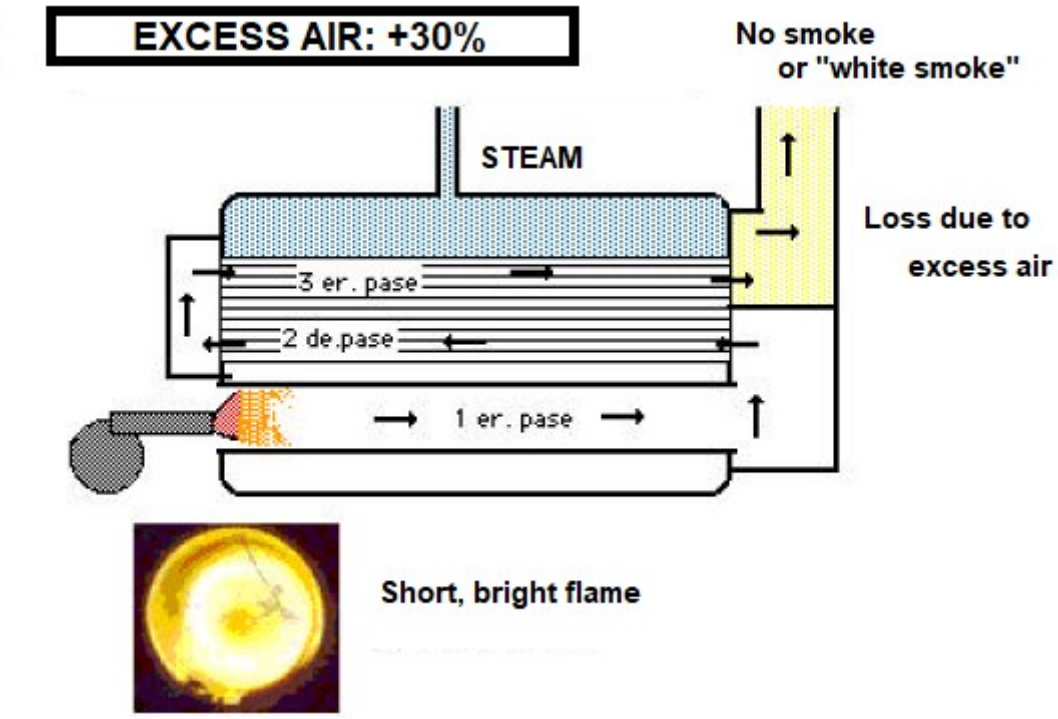
2-Good combustion:

The flame is relatively short and orange, and the fumes are only slightly perceptible (a light caramel color). CO2 levels will be between 12% and 14%, O2 between 3.5% and 6%, with no CO and almost no soot. These values depend on the type of burner and boiler.



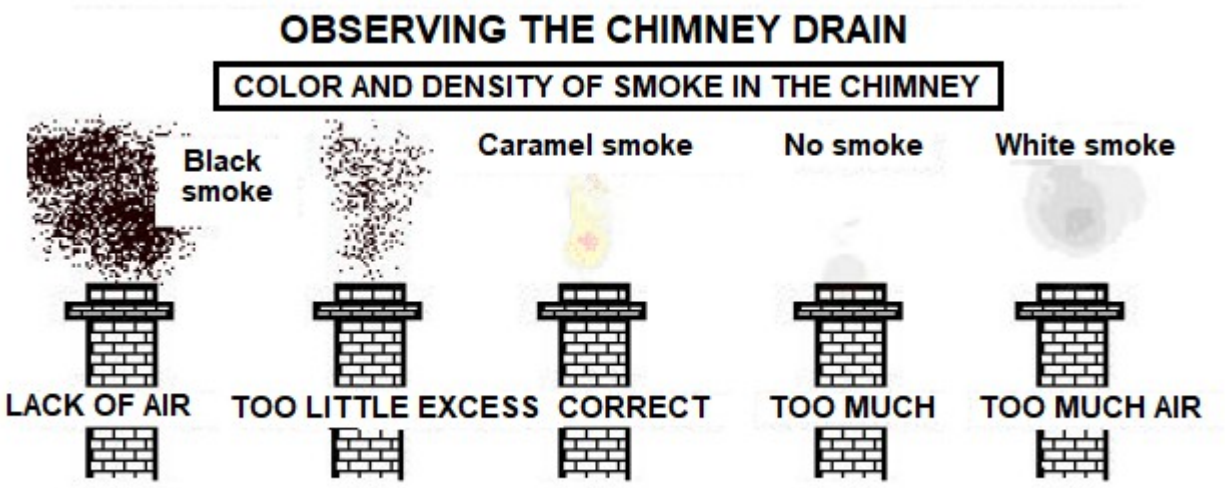
3-Excess air:

the flame is very short and a bright orange: almost white, no smoke is seen in the chimney or if the excess is very large the smoke is white. (CO2 less than 12%, O2 greater than 6%, depending on the type of burner and boiler).



4-Poor combustion:

There may be a lack of air or an excess of air in certain combustion areas due to poor atomization or poor regulation of the air-fuel interaction. Poor atomization, or fuel that is too cold or too hot (rotary cup), water in the fuel (spraying), etc.



The use of fuel additives promotes atomization in some cases (mechanical atomization, by lowering viscosity), but combustion problems must be corrected by adjusting the burner.

The use of additives generally emulsifies water (preventing water from settling in the fuel oil in the service tanks; if contamination is significant, this causes difficulties). Fuel additives can be designed to improve combustion by introducing incandescent particles into the flame (they contain salts that release particles which, upon contact with the flame, produce light and thus heat that accelerates combustion).

In other cases, their function is to neutralize sulfur and vanadium, or improve fuel circulation in the cold zone (filters and tanks, preventing or dissolving sludge from the decomposition of the fuel oil itself).

It must be clear that low flash point additives should not be used. The flash point is the temperature at which the fuel ignites momentarily in a container open to the atmosphere upon contact with a flame; the fire point is the temperature at which the fuel surface continues to burn for at least 5 seconds. This is dangerous because the formation of flammable vapors can cause an explosion in a home, tank, or building.

The flash point of fuel oil is approximately 65°C (149°F). It is generally heated for circulation to between 40°C (104°F) and 60°C (140°F), and then for atomization, the temperature will generally be no less than 100°C (212°F) and up to almost 145°C (293°F). This means that a low flash point additive is not suitable. (flash point) will produce explosive gases.

When purchasing additives, this is an important point to consider: the additive should have a flash point equal to or higher than that of the fuel.

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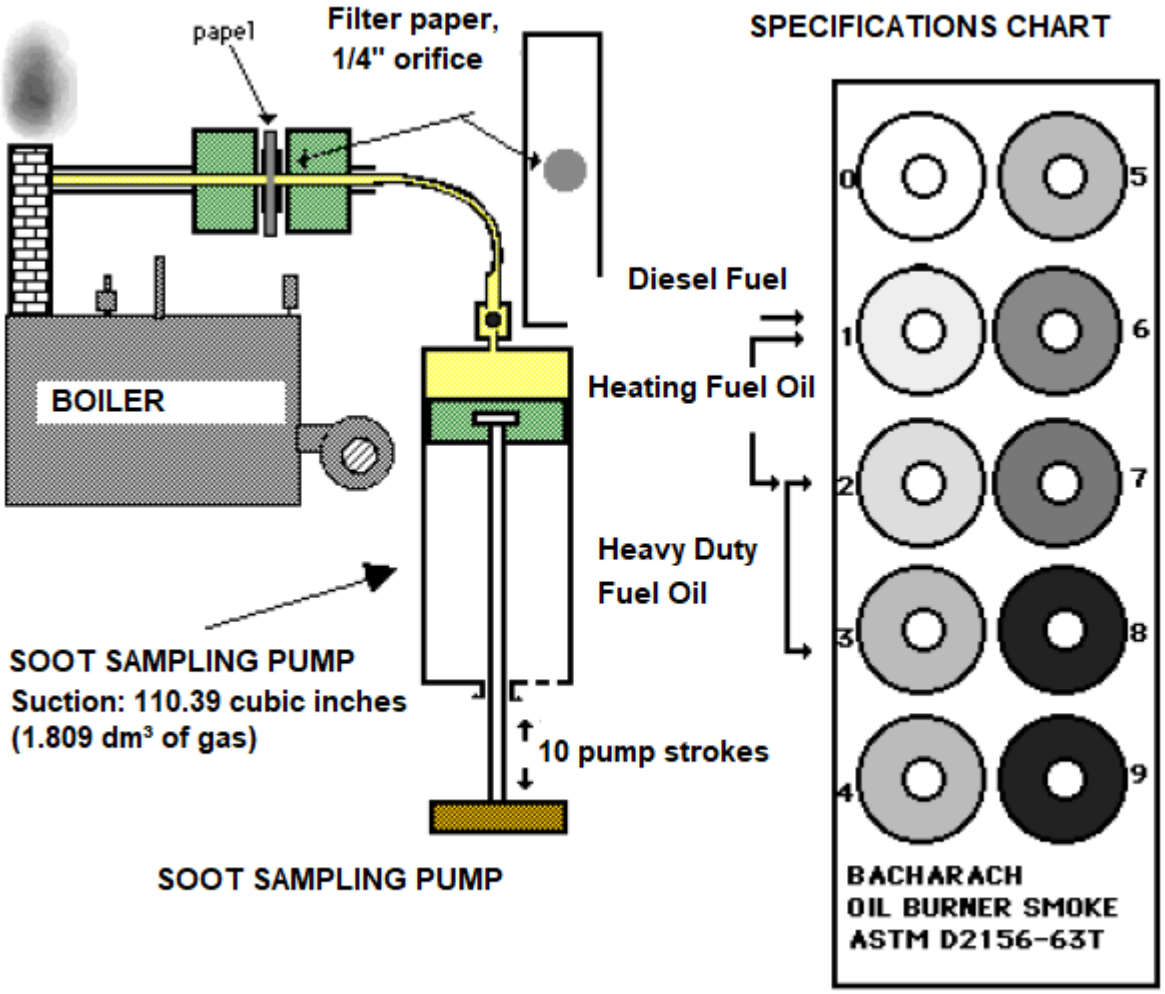
To monitor soot formation in flue gases, in addition to visual observation of the gases at the chimney outlet (which is an estimate), a soot sampling pump such as the Bacharach can be used (which indicates soot levels in the gases more accurately than visual observation).

This follows the standards established by ASTM D2156-63T, which states that a soot stain on filter paper, caused by a flue gas volume of 110.39 cubic inches (1.809 dm^3) passing through a 1/4" orifice (6.35 mm diameter), is compared to a chart with a corresponding soot number (these are circles with a soot-like color of varying shades, each with a 1/4" hole in the center through which the stain left on the filter paper is viewed for comparison).

For example: when burning Heavy Fuel Oil, the maximum acceptable soot level is #3, although with a burner in good condition, #1 can be achieved.
For lighter liquid fuels, the maximum acceptable soot level is lower, as it is possible to work with very low soot formation, as in the case of Gas Oil, whose maximum level will be #1.

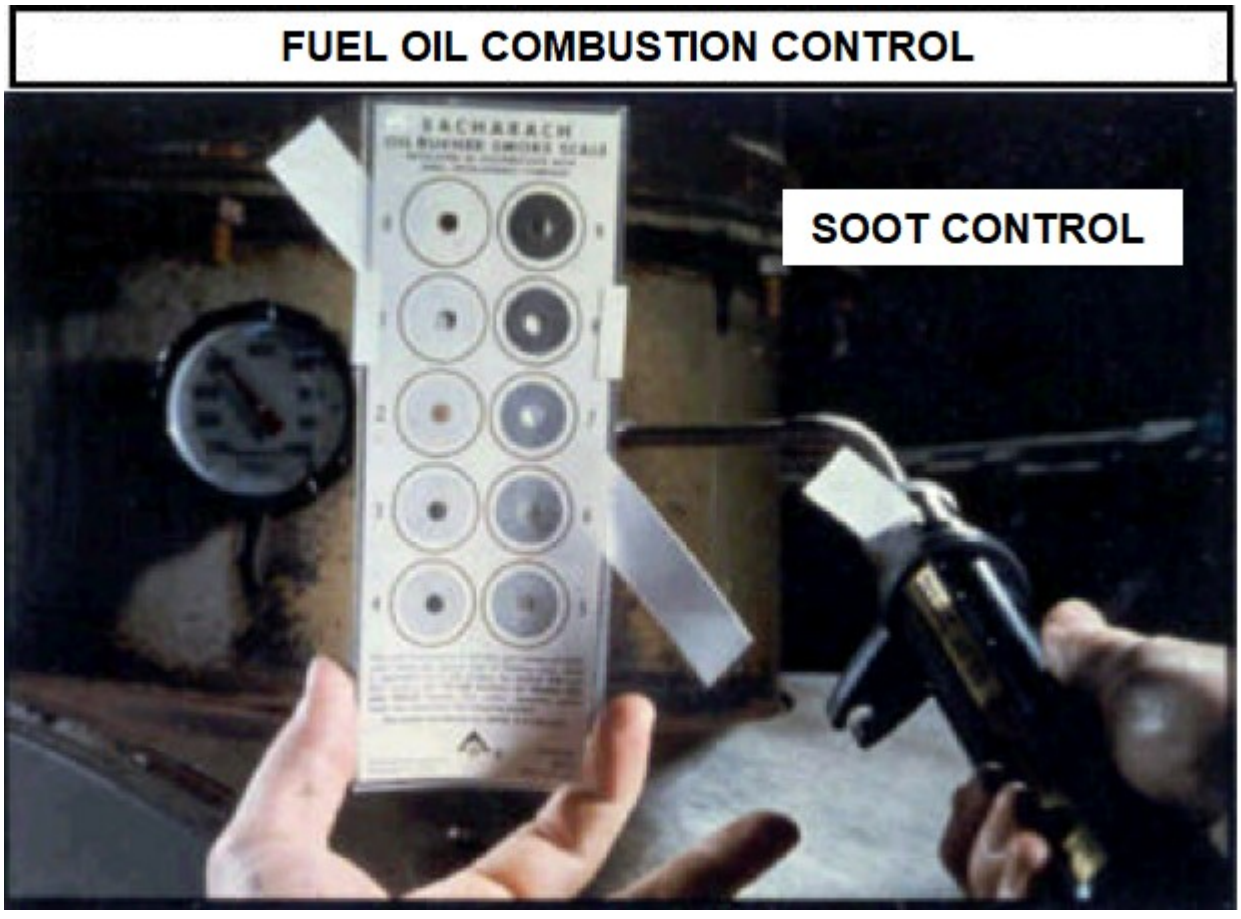
See the diagram below.


papel
Filter paper,
1/4" orifice
BOILER
Diesel Fuel
Heating Fuel Oil
Heavy Duty
Fuel Oil
SOOT SAMPLING PUMP
Suction: 110.39 cubic inches
(1.809 dm³ of gas)
10 pump strokes
SOOT SAMPLING PUMP
SPECIFICATIONS CHART
0
5
1
6
2
7
3
8
4
9
BACHARACH
OIL BURNER SMOKE
ASTM D2156-63T

Excess air (CO2 below 10% or O2 above 5%) is not a sufficient indication that there will be no soot in the flue gases. Therefore, measurement with the Soot Sampling Pump (Bacharach®) is necessary, as incomplete combustion can occur for many reasons.

Simply observing flue gases is now completely insufficient. Generally, different fuel atomization methods mean that some work better with heavier fuels (such as atomization with steam or hot compressed air, and some "rotary cup" burners, which improve combustion of this otherwise difficult-to-burn fuel).

Of course, the operating cycle of a boiler also plays a role. A boiler with frequent starts and stops will produce significantly more soot because combustion is very unstable during the "start-up" period, leading to soot production until the flame stabilizes.



If the boiler shuts down due to a power outage or lack of water, close the steam valve (the burner will be off, but tubes may remain exposed to residual heat, without wáter level to cool them, if the steam valve is not closed).

When shutting down the boiler at the end of the day, the burner must be turned off (a post-purge of gases with air must be performed, since fuel may have leaked and formed explosive gases.

The steam valves must be shut off, the air vents must be closed, the fans and fuel pumps must be turned off (as well as the fuel heaters, the fuel control valve, the continuous purge valve, etc.), leaving the water supply running as long as there is steam pressure inside the boiler.

Do not force the pressure drop; the boiler will cool unevenly, creating harmful stresses.

After about 15 minutes of inactivity, it's advisable to perform a series of purges (as the sludge will tend to settle).

Once the pressure has dropped to almost zero, the boiler should be **flooded with treated water** (to prevent corrosion from oxygen in the air), leaving a water seal in place to compensate for the expansion and contraction of the water (in some cases, leaving the feed valve open is sufficient).

If the boiler is not flooded, a vacuum is created as it cools, which can cause reverse pressure stresses (atmospheric pressure). This must be taken into account in some types of boilers (as it can affect their structure, especially in low-pressure boilers) and can cause "suction" of products heated by the direct steam, contaminating the boiler water (digesters, vats, etc.) or the entry of oxygen, which causes corrosion ("pitting").

When the boiler is left in use for extended periods, the water conditions must be monitored to minimize corrosion.

To prevent corrosion, the water's pH must be above 10.5, and there must be sufficient chemicals to absorb (or combine with)

any oxygen that may enter the boiler (even with the boiler flooded and with a water seal that allows for free expansion and contraction without atmospheric air entering).

Prevent steam from other boilers from entering the shut-down boiler (due to leaks in the steam valves), as the steam produces a corrosive condensate that affects the shut-down boiler.

The condensation at the top creates conditions that promote corrosion.

Under no circumstances should the boiler be left with a low steam level (consuming steam even with the burner off).

When the tubes are exposed, they are susceptible to corrosion. Therefore, in the event of a **power outage, immediately shut off the steam supply** to prevent the boiler from losing its normal steam level (thus avoiding corrosion and overheating of the tubes).

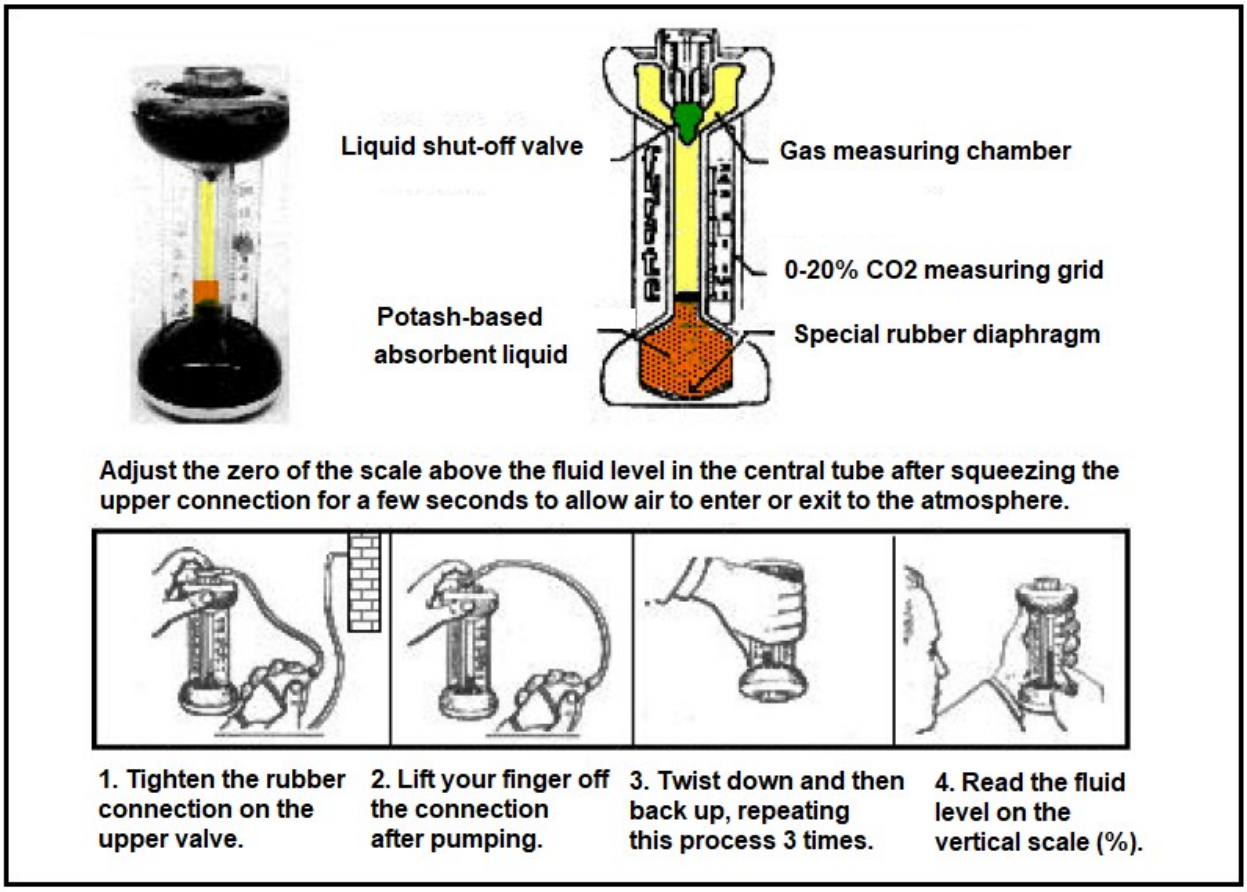
When the shutdown period exceeds several months and the boiler will not be used immediately, **"dry storage"** is recommended.

This involves draining the water, cleaning out the internal sludge with a hose, and completely drying the interior of the water and steam chamber (using hot air or electric heaters).

Maintain the interior dry during this period by using temperatures higher than ambient or by applying **moisture-absorbing products** (such as sealing the boiler with quicklime or silica gel). Periodically inspect the boiler and replenish the absorbents, taking care not to allow them to fall inside (lime is corrosive).

It is advisable to disconnect all pipes that could introduce water or moisture into the boiler (steam pipes, water supply lines, etc.).

Clean the soot-covered areas (by brushing, using compressed air, or with hot alkaline water) and dry them thoroughly (use heaters if necessary).


Liquid shut-off valve
Gas measuring chamber
0-20% CO2 measuring grid
Potash-based absorbent liquid
Special rubber diaphragm
Adjust the zero of the scale above the fluid level in the central tube after squeezing the upper connection for a few seconds to allow air to enter or exit to the atmosphere.
1. Tighten the rubber connection on the upper valve.
2. Lift your finger off the connection after pumping.
3. Twist down and then back up, repeating this process 3 times.
4. Read the fluid level on the vertical scale (%).

FYRITE EQUIPMENT FOR MEASURING CO2 AND O2 IN BOILERS

The FYRITE (Bacharach) is a chemical absorption device for measuring CO2; similar devices exist for O2.

In the case of CO2 (carbon dioxide), potassium hydroxide (KOH) is used as the absorbent at a specific concentration (it absorbs the sum of CO2 and SO2, with the SO2 content generally being very low).

The measurement is taken in a hydraulic column (a tube containing gas and liquid) that is subjected to the weight and pressure of the solution as it absorbs CO2. A membrane at the bottom of the liquid chamber also absorbs atmospheric pressure (after calibration to 0% by opening the device to the atmosphere and then adjusting the scale to zero).

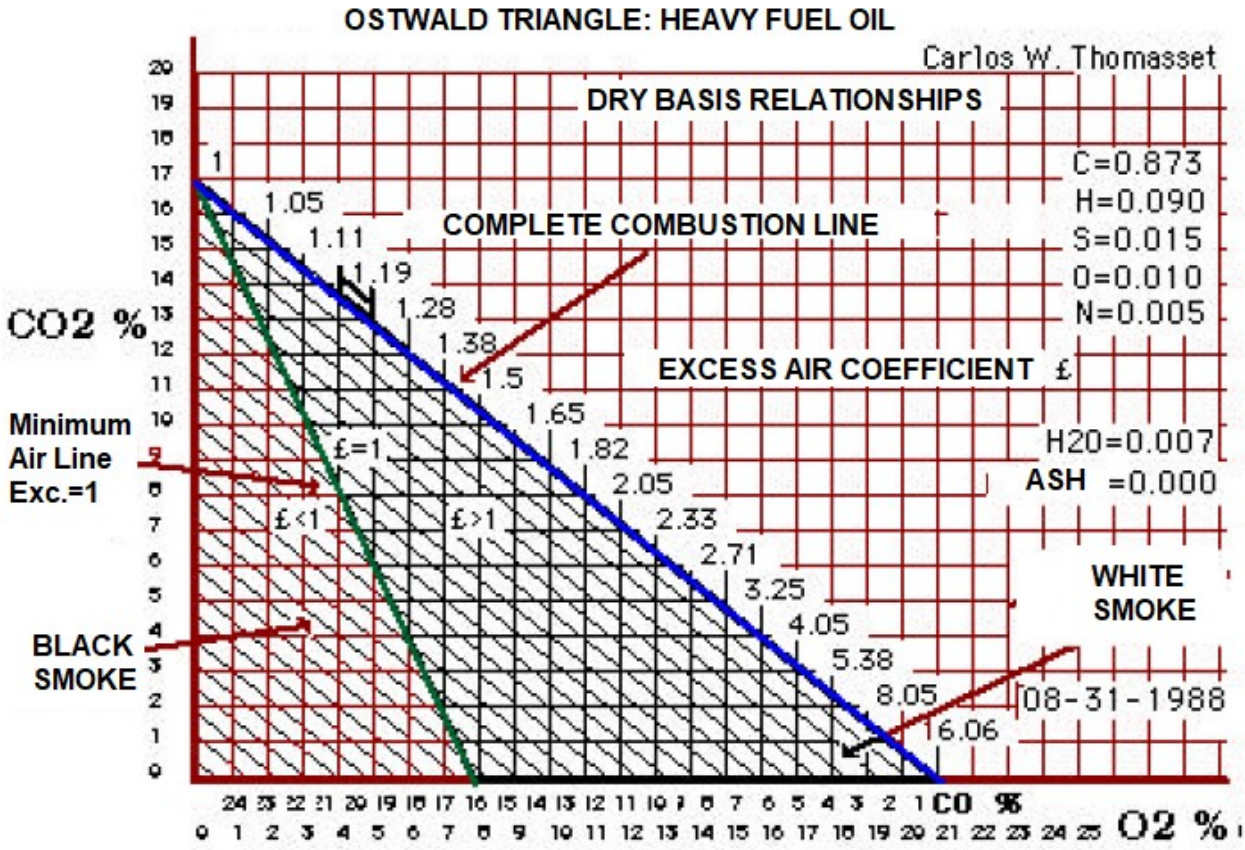
Once the sampled gas trapped in the upper chamber is mixed with the potash, the CO2 is chemically absorbed, which lowers the internal pressure. Atmospheric pressure then pushes the diaphragm

to equilibrium. Reading the level that rises in the vertical central tube at this point will give the CO2% reading.

The O2 meter operates similarly, although the absorbent is a different selective chemical, meaning it only reacts with O2. (The problem with the O2 meter is that any air intrusion, when the equipment is at rest or stored, will deplete the liquid, something that doesn't happen with the potash.)

These devices have the great advantage of simplicity and ease of maintenance (or repair); their error, although it can be up to 0.5%, is sufficiently precise for adjusting combustion in the most common boilers.

Remember that these devices measure gases in dry relation (considering water in the flue gases as absent, i.e., condensed).



It must be considered that each Ostwald Triangle, as well as the theoretical flue gas curves, are plotted with values of the % of gas on a "dry basis" (and depend on the composition of the fuel and the air at sea level). That is, it is considered that the water that the fuel brings plus the water produced by the hydrogen contained in the fuel is considered as if it were "condensed" or transformed into water by cooling (it does not exist as if it were another gas, like CO2, O2, CO, N and other gases if there is poor combustion).

Therefore, when using an instrument to measure gases, we must understand its operating principle. If it measures "hot" gases, the water vapor in the flue gases will affect the measurement (as is the case with zirconium oxide cells for measuring oxygen). Other instruments cool the gases to ambient temperature, but some evaporated water remains, slightly influencing the percentage reading.

Orsat, Fyrite, and other absorption instruments measure on a "dry basis." While the water vapor condenses, the small amount that remains is "compensated" in the measurement.

HEAVY FUEL OIL HEATERS and their problems:

The use of heavy fuel oil (also for heating fuel oil, that is, heavy fuel oil whose viscosity has been reduced by adding diesel oil by almost 30%, which facilitates pumping at low temperatures and then, during atomization, must be used at a lower temperature than required for heavy fuel oil, allowing it to be used in smaller burners whose atomizing nozzles cannot properly atomize the heavy fuel oil).

The preheating of heavy fuel oil for pumping is generally done in storage tanks using steam coils (whose condensate should be discarded in case of contamination if one of the coils is punctured). The preheating is done to a temperature at which it can be pumped without problems (an excessive temperature can be counterproductive for the operation of the pumps and even for their sealing in the packings).

This temperature is generally around 50°C 122°F (the heat required to raise the temperature of 1 kg of fuel oil by 1°C, called specific

heat, is approximately 0.5 kcal/kg or 0.9 BTU/lb, that is, half the amount required to raise the temperature of 1 kg or 1 liter of water to the same temperature).

Given the pumping distances, both supply and return, it is necessary to have the pipes insulated and also with heating elements (steam or hot water tracers, as well as electric ones, these elements are in contact with the metal of the F. Heavy Oil pipe and transmit a certain temperature to keep the fuel in the vicinity of 50ºC 122°F).

Steam or hot water heat tracer systems are simple iron or copper pipes in contact with the fuel line and connected to it by means of "heat bridges," always beneath the insulation.

In electrical tracers, there is a very interesting variety, from a simple cable with a "resistive" effect that, when a current passes through it, heats up like a stove, to elements with cables that actually operate at very low voltage and high current, causing a heating effect through the alternating magnetic field in the fuel line (the latter is widely used in oil pipelines that transport fuel through cold regions and over long distances, such as in Alaska, Canada, etc., although it can also be used in boiler systems).

When these tracers are not available, in smaller installations, there are two ways to start pumping the cold fuel:
1.- Stop the boiler using a lighter fuel such as heating oil or diesel or gas oil,
2.- Heat all the pipes with a gas torch before attempting to start the heavy fuel oil circulation pumps.

In the boiler room, fuel can be:

a- drawn by the burner's fuel pump (under negative pressure);

b- taken from a "low-pressure fuel ring," that is, a supply and return piping system to the fuel tank;

c- drawn from an elevated service tank (under pressure—higher than the pump, which presents significant problems in the event of fires, especially due to spills);

d- drawn by the pump from a sealed cylinder (pressurized towards the pump, providing fuel for a few minutes, but with the significant advantage of being sealed against spills).

I have found this last system to be very simple and very safe,

provided it is properly designed. It is similar to the ring system but has the advantage of better managing fuel pressure fluctuations when pumping conditions change.